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Urban landscape pattern design from the viewpoint of networks: A case study of Changzhou city in Southeast China

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ABSTRACT

Urban landscape pattern (ULP) is becoming increasingly important for the sustainable development of regions and the whole world. Knowing the ULP status is crucial for making decisions to avoid ecological disasters, reducing environmental problems and industrial pollution, and harmonizing urban development and natural conservation. To link and harmonize various landscape elements and flows in the ULP, this study developed a theoretical scheme from a network viewpoint to explain the spatial interactions among landscape elements and flows. Using a case study of Changzhou city located in southeastern China, this paper tried to integrate ecological factors and socioeconomic conditions using landscape functions modeling and network analysis to establish strategies for ULP design. Because an urban landscape is highly complex with various social, economic, and natural elements, urban landscapes were classified into four subtypes, each with its own specific appearance. Then the paths of socioeconomic and ecological flows were determined using a least-cost distance model. The overall pattern of linkage paths among the ecologically fragile areas could help identify the areas with high ecological risk in Changzhou. For ecologically sustainable, economically sound, and socially just development, a scheme for ecological rehabilitation and security-pattern design was proposed to reduce ecological risks. Finally, this study discussed how to balance economic and ecological needs from the viewpoint of network theory and how to optimize landscape patterns through enhancing functional linkage and strengthening structural connectivity.

1. Introduction

Global ecological security is becoming increasingly important because of severe pollution and ecosystem degradation, including air pollution, water pollution, soil loss and degradation, desertification, decrease in forest cover, the greenhouse effect, destruction of the ozone layer, and decrease in species diversity (Zhao and Yang, 2007; Fu et al., 2010). Ecological security functions are highly influenced by various human activities, and in return, the efficiency of human activities will also be affected by the state of regional ecological security (Zhou et al., 2010). In the 1990s, China began to pay attention to ecological security problems. The 2000 Compendium of National Environmental Conservation, published by the State Council of China (2000), established the objectives of improving environmental quality and maintaining national eco-environmental security and specified the latter as the principal mission of national environmental conservation activities.

The definitions and emphasis of the ecological-security concept vary with different authors, including improvement of ecosystem services (Costanza, 1997; Zhu et al., 2003); maintenance of ecosystem health (Schaeffer et al., 1998; Kong et al., 2002), and remaining within environmental carrying capacity limits. Another, more specific definition focuses on the security of natural and semi-natural ecosystems, that is, the overall integrity and health of ecosystems (Xiao and Chen, 2002; Yang and Lu, 2002; Ma et al., 2004). It has been generally accepted that the ecological security concept comprises the security of nature and of human beings, including nature conservation, economic and social growth, and human life, health, rights, safety, and adaptive abilities with respect to ecological risks (Xiao and Chen, 2002).

Typical urban landscape is a kind of complex social-economic-natural ecosystem. Natural and physical elements are its primary components, economic activities and metabolic processes continue and evolve, and human needs drive its succession and evolution (Wang, 1991; Burkhard et al., 2010). A city does not exist independently and is composed of many subsystems with specific structures and functions. The ideal urban landscape is harmonic, efficient, continuous (Dong, 2002), and with a reasonable set of

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structures and relationships (Li and Xie, 2005). Therefore, safe urban landscape is able to maintain its organization, configuration, and flexibility in the face of risks at a specific spatiotemporal scale (Guo, 2002; Xie and Li, 2004). Urban ecological security means environmental and developmental safety in the future and could also be understood to mean the health and balance of the urban ecosystem (Wang and Ouyang, 2007). The carrying capacity of an urban ecosystem is limited, so when optimizing the urban landscape, it is necessary to maintain adaptation, cooperation, and symbiosis among landscape elements (Zhang et al., 2007).

Many landscape metrics are used in environmental assessments (Jones et al., 2001; Wade et al., 2003) and to help landscape planning and decision making (Hobbers, 1997; de Groot et al., 2010). In this context, the network is an appropriate concept which provides a viewpoint and a method to break down a complex landscape system, linking and harmonizing landscape functions across multiple scales (Green and Sadedin, 2005). A network can be seen as an entity composed of nodes and corridors, and conceptions of network have therefore often been used to reflect the spatial relationships and configurations of landscapes. In ecology, the concept of networks has been used to describe interactions such as competition and symbiosis among various organisms and communities (Zong, 1999). In addition, in landscape planning and biodiversity protection, the ecological network is a widely accepted framework for it can help maintain or strengthen landscape eco-functions through reorganizing the spatial arrangement of landscape elements (Opdam et al., 2006). Furthermore, the connectivity of landscape patterns can also have an effect on the spatial diffusion of landscape functions. Greenways, waterways, and transportation networks can affect the movement and flow of organisms, minerals, nutrients, and information (Antrop, 2004; Arendt, 2004), and landscape connectivity and patch size are related to various ecological processes (McGariga and McComb, 1995; Li et al., 2005).

For the gradient of urbanization, changes in ecosystem characteristics can reflect the intensity of human influence on the environment (Weng, 2007). To examine the spatial effects of urban landscape patterns and functions, this study targets the questions of cost-distance and least-cost paths in the ULP. Cost-distance is similar to Euclidean distance, but instead of the actual distance from one point to another, it represents the shortest weighted distance (or accumulated travel cost) from each cell to the nearest cell in the set of source cells. Another minor difference is that cost-distance measures distance, not in geographic units, but in cost units. These costs may be travel time, dollars, preferences, or other costs. Cost-distance analysis could help to define the area of influence of an economic center (Hare, 2004), improve the results of landscape optimization (Niu et al., 2002), identify suitable paths for traffic (Chen et al., 2004) or species migration (Schadt et al., 2002), and quantify the degree of landscape-function connectivity on different types of cost surfaces.

Landscape is a spatial structure formed by contiguous corridors and patches. Interactions of flow, energy, and materials in a landscape depend on landscape network structure. To optimize ULP, this work included the construction of a landscape network based on least-cost modeling which is capable of reconfiguring landscape patterns to avoid or buffer incompatible interactions, thus providing a new research framework for ULP design.

2. Theoretical framework of landscape networks

A landscape network is comprised of nodes, subnodes, and connective units that may be large patches, patches, or corridors (Fig. 1). Classifications of landscape networks depend on the viewpoint used. A landscape network could be classified into corridors and patches according to the shape of its landscape elements (Fu et al., 2001). With respect to landscape function, a landscape network also includes ecological and economic networks. The ecological network comprises urban parks, green corridors, forest belts, and other natural conservation areas which could protect biodiversity and enhance eco-functions (Cook, 2002; Jongman et al., 2004; Schuller et al., 2000; Kühn, 2003). The economic network concept developed out of computerization and is composed of traffic infrastructure and socioeconomic centers.

2.1. Ecological landscape networks

The ecological network concept was already developed in urban planning by the beginning of the 20th century (Jongman et al., 2004). Based on the division of territory between the urban area and the natural environment (Antrop, 2004), the construction of an ecological landscape network could protect diversity and enhance the exchange of materials and energy (Schrijnen, 2000) through connecting conservation areas, areas of limited development, and greenways, parks, and other ecological "stepping stones" within cities.

The ecological network is a famous concept as well as a strategy for biodiversity protection and environmental optimization (Yan and Tan, 1998) at various scales. The basic function of an ecological network is to provide paths for wildlife, energy, and other materials to move and exchange in a fragmented landscape. Its configuration can be summarized at the regional, landscape, and patch scales based on related research (Table 1).

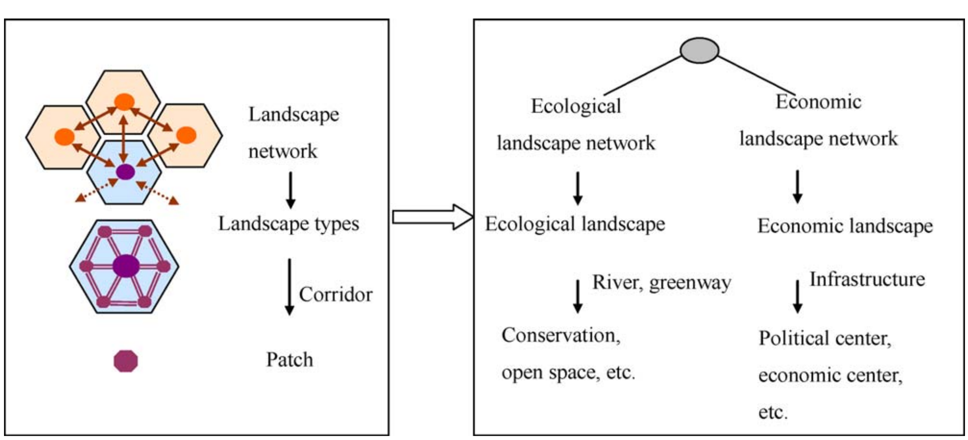

Fig. 1. Conceptual framework and principal composition of landscape networks.

Table 1
Composition of ecological landscape network at different scales.

Scale	Node (point)	Corridor (line)	Function service area
Regional scale	Global conservation of significant animals and geological or cultural landscapes	Concrete landscape connective elements. Natural flows could affect species diffusion (airflow)	Natural ecosystem (vast boundaries, complex structure full, undisturbed)
Landscape scale	Conservation or limited development area for preventing natural disasters or maintaining resources	Primary river, greenway or other natural landscape with connecting functions	Comparatively unattached ecosystem such as a watershed
Patch scale	Ecological stepping stones such as open space, remaining habitat	Greenway or blue-way in urban landscape. Hedge in agricultural landscape	Services area of nodes and corridor at this scale

Table 2
Composition of economical landscape network at different scales.

Scale	Node (point)	Corridor (line)	Function service area
Regional scale	International metropolis with politic, economic, communication functions	Concrete corridor (traffic infrastructure) Abstract corridor (flows of population, information, money and services)	Urban agglomerations with central city and hinterland cities from socio-economic driving forces
Landscape scale	Administrative center Economic activities center Traffic center	Primary traffic lines that connect with regional political, economic, and traffic centers	Urban living perimeters with unattached social economic areas
Patch scale	Commercial, financial, information and technological centers in a city	Roads, routes	Services area of nodes and corridor at this scale

2.2. Economic landscape networks

Fast transmission and communication of knowledge enable cities around the world to interact frequently. Based on the connection between society and economy, an urban functional network consists of traffic infrastructure and socioeconomic centers supporting the movement of information, capital, technology, and materials. Each center can be assigned a level depending on the services it provides and the influence it exerts, considering factors such as consumption levels, traffic, and general welfare.

In the process of urbanization, a city as it grows from a single point to a network configuration exerts strong social and economic influences that require temporally and spatially evolving processes. The levels and structure of an urban functional network are caused by interactions between human activity and the natural environment and are affected by administrative activities, economic development, and infrastructure expansion (Yao et al., 2001). Because the levels and structure of an urban functional network are distinct at different scales, this study discusses network configurations including points, lines, and areas at the regional, landscape, and patch scales based on related research (Table 2).

2.3. Harmonizing different landscape networks

Interactions between ecosystems and socioeconomic systems produce landscape complexity. At present, because of the large resource requirements of human beings and the demands of urban maintenance, an urban landscape has an advantage over a pure ecological landscape in functional conflicts over the use of space. Therefore, a key element of urban ecological security pattern construction becomes how to harmonize urban development and natural conservation and reduce environmental problems and industrial impacts. Harmonizing ecological and economic landscape networks involves identifying key landscape units or structures while maintaining various landscape services. Once an ecologically fragile area affected by human activities has been identified and ecological functional connections has been defined, then changes or adjustments to land uses could be helpful to optimize various landscape networks and promote urban development and conservation.

3. Methodology

3.1. Study area

Changzhou city is located in Jiangsu province, northwest of the Yangtze River delta in southeastern China (Fig. 2). Changzhou is characterized by flat landforms and warm cloudy weather. Nearby rivers and lakes offer abundant water resources, and the water system in Changzhou is directly linked to Taihu Lake and the Yangtze River. With more than 2500 years' history, many cultural heritage sites and river routes could be integrated to develop ecological and cultural tourism. Because the dominant wind direction is opposite to that of the river flow, because frequent calm winds can reduce air circulation, and because many interconnecting rivers and drainage channels exist, water pollution has become a serious restriction on urban growth. An urban ecological security pattern in Changzhou should therefore focus on planning of spatial buffers with forest and grassy areas to improve air circulation and water quality.

3.2. Classification of thematic mapper (TM) images and landscape reclassification

The data on landscape types used in this research are derived from a series of TM images from Landsat 5 acquired in 2006 with

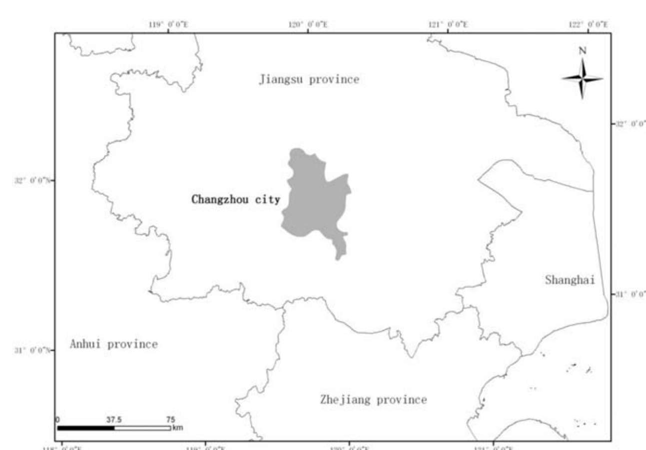

Fig. 2. Geographical location of study area.

Table 3
Landscape reclassification scheme.

Reclassified landscape types	Original land-use type	Description of basic function
Red landscape	Industrial areas, commercial areas and administrative areas	Supporting residence, producing and other economic activities
Gray landscape	Railways, highways, roads and paths harbors, airports and transport stations	Maintaining external and internal communication transferring energy, money and information spread abroad
Green landscape	Open spaces, plantations, woodlands and other green units	Producing agricultural products micro-climate regulation providing outdoor space inducing pollution and absorbing noise
Blue landscape	Rivers, lakes, reservoirs and swamps	Improving local temperature maintaining biodiversity

orbit sequence numbers 119–138. Before analysis, following atmospheric radiance calibration and initial geometric rectification of all the TM images using the ENVI software, a number of reference points were selected from a 1:50,000 scale topographic map, and the TM images were rectified to a Gauss-Kruger projection with a pixel resolution of 30 m × 30 m, using nearest-neighbor rules provided by ENVI, to ensure that the error was controlled to less than one-half the pixel root mean square (RMS) error.

Landscape classification and mapping using remotely sensed data has become a commonly used technique, mainly based on its ability to provide information on land surfaces and human activities. Supervised maximum likelihood classification methods were used in this work. Then the accuracy of the image was evaluated using ground data points not used in the classification process. The equal-control-point methods provided by the ENVI software were used, with at least 30 points for each class. The overall accuracy assessment was checked for each image individually, and an image was accepted if its accuracy was greater than 80% (determined using 580 random points). After the accuracy evaluation, all images were clumped and vectorized using the ENVI software. Coverage area data were preprocessed using the ArcGIS software to eliminate areas less than 0.27 ha (corresponding to 3 pixels × 1 pixel) for faster spatial analysis.

Eight kinds of landscape elements were identified: cultivated land, orchards, forests, built-up areas, traffic infrastructure, water bodies, grasslands, and miscellaneous unused land. The meaning of each class generally conforms to the standard classification system used for land cover in China. The results were considered to be generally acceptable, with an overall classification accuracy of 87% and a Kappa-statistic value of 0.92.

Based on the results of this classification, the landscape elements were reclassified into four color categories: red, gray, blue, and green (Table 3). This classification scheme was chosen because it reflects the intensity of land use and the visual and functional difference of land-use types. The red landscape type represents built-up areas that support residential, manufacturing, and other socioeconomic activities; the gray landscape type includes various traffic and communications corridors such as roads, traffic facilities, and utilities which provide external and internal transfer and communication of energy, goods, and information. The green landscape type is composed of natural areas, conservation areas, and green corridors with various ecological functions. The blue landscape type consists mainly of wetlands and waterways, including rivers, lakes, reservoirs, and marshlands, which could help maintain regional biodiversity and improve local climate conditions.

3.3. Cost-distance analysis

Cost-distance represents the cost involved in moving through any particular cell in a given landscape, which can be viewed as a qualitative description of landscape pattern (although the description is still expressed in numerical terms). Moreover, cumulative cost-distance provides information on the interaction of landscape types or units, for example the rate or speed of exchange of energy, materials, and information. In an urban area, flows of energy, materials and information move through the least-cost paths and intersection nodes (Wu and David, 2002), and therefore a least-cost model was used to optimize the spatial arrangement and composition of the nodes and paths which could promote ecological functions and services in the urban area.

The key to performing a cost-distance analysis is to define the cost grid and then to compute the cumulative cost-distance grid. First, a cost grid assigns impedance values, using a measurement system with uniform units, that represent the cost involved in moving through any particular cell. The value of each cell in the cost grid is assumed to represent the cost per unit distance of passing through the cell, where the unit distance corresponds to the cell width. Second, the creation of a cumulative cost-distance grid using graph theory can be viewed as an attempt to identify the lowest-cost cell and to add it to an output list. This is an iterative process that begins with the source cells. The goal is to assign each cell quickly to the output cost-distance grid.

When moving from a cell to one of its four directly connected neighbors, the cost to move across the link to a neighboring node is the cost of cell 1 plus the cost of cell 2 divided by 2 (Fig. 3):

$$L_1 = \frac{C_1 + C_2}{2}, \tag{1}$$

where C_1 is the cost of cell 1, C_2 is the cost of cell 2, and L_1 is the length of the link from cell 1 to cell 2.

If the movement is diagonal, the cost to travel over the link is the square root of 2 times the sum of the cost of cell 1 and the cost of cell 2 divided by 2:

$$L_1 = \sqrt{2}\frac{C_1 + C_2}{2}. \tag{2}$$

The cumulative cost can then be determined as shown in Eq. (3):

$$AC = L_1 + L_2 = L_1 + \frac{C_2 + C_3}{2}, \tag{3}$$

where C_2 is the cost of cell 2, C_3 is the cost of cell 3, and AC is the cumulative cost of moving into cell 3 from cell 1.

However, when determining the cumulative cost for diagonal movement, Eq. (4) must be used:

$$AC = L_1 + L_2 = L_1 + \sqrt{2}\frac{C_2 + C_3}{2}. \tag{4}$$

4. Results

4.1. Spatial structure of economic landscape networks

Using a 1 km × 1 km grid as the basic analytical unit, the spatial distribution of the functional intensity of the area percentage of

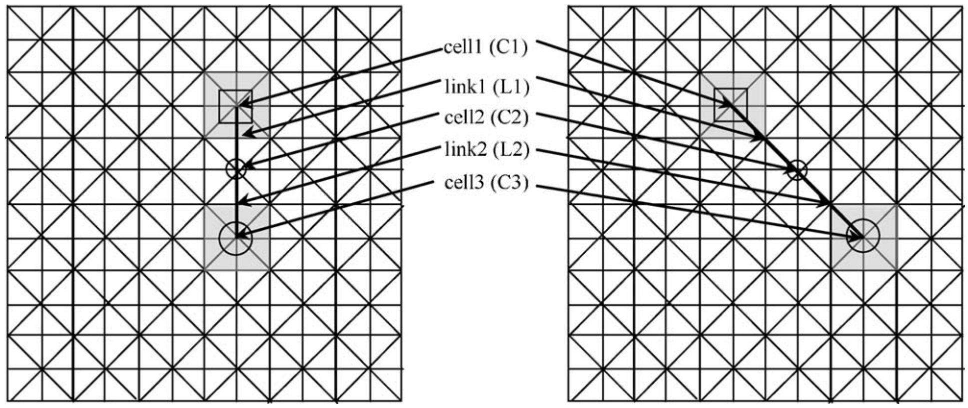

Fig. 3. A view of nodes and links through the graph theory: horizontal or vertical node calculations (left); diagonal node calculations (right) (ESRI, 2001).

economic landscape types (red or gray landscapes) was quantified in grid units. The units with an area proportion of these types of more than 80% were then extracted as key economic functional nodes. In fact, all eight red landscape nodes identified were important socioeconomic, political, or industrial centers. Using road density as a cost-distance variable, a least-cost distance model was constructed to determine the paths with minimum cumulative cost values among the red nodes. The simulated paths among the key gray nodes were evaluated using an area-based index as the cost-distance variable.

Fig. 4 presents the overall spatial structure of the economic landscape network. Economic flows in red landscape areas occur along major traffic routes such as railroads and highways. In southern Changzhou city, the economic functional linkages near Ge and Taihu Lakes should be enhanced by integration of some dispersed industrial areas. Among the economic centers, gray landscape plays an important role in linking all kinds of economic landscape. As for red landscape, the structural connectivity near Ge and Taihu Lakes should be improved through strengthening and integrating the traffic infrastructure in southwestern Changzhou.

4.2. Spatial structure of ecological landscape networks

Similarly to the analysis of economic landscape networks, the key nodes and paths comprising the ecological landscape networks were extracted using a least-cost distance model. In blue landscapes, key nodes included major marshland areas and the intersection points of major tributaries with the Yangtze River, Tai Lake, and Ge Lake. The cost surface of the blue landscape type was quantified using area proportion in grids. As for the green

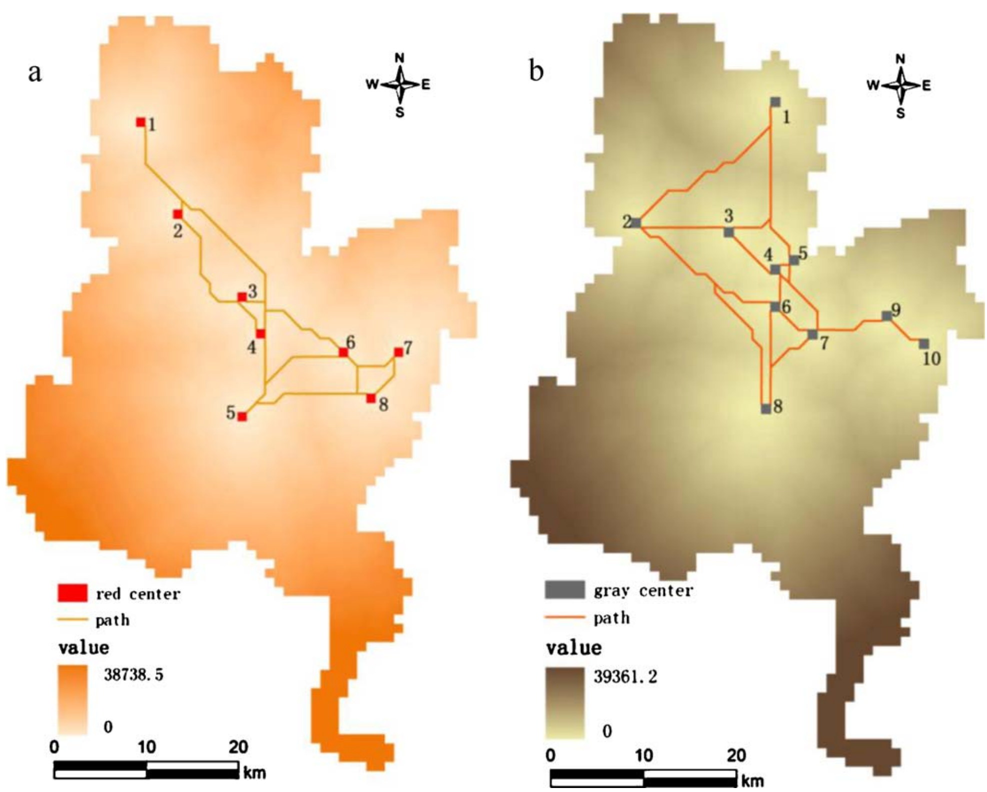

Fig. 4. Nodes and paths of economic landscape networks. The accumulated value of cost distance is derived from least-cost distance modeling. Bright areas correspond to high cost areas and darker areas correspond to low cost areas. (a) Red landscape network (1, Xixiashu; 2, Tangzhuang; 3, Administrative center in Changzhou; 4, Chashan; 5, Wujin; 6, Dingyan; 7, Hengshangiao; 8, Qishuyan). (b) Gray landscape network (1, Yanjiang industry area; 2, Benniu; 3, Xuejia; 4, Sanjing Community; 5, Hehai Community; 6, Hongmei Community; 7, Dongnan industry area; 8, Intersection of Changcao highway and Changcheng highway; 9, Hengshanqiao; 10, Intersection of Huning highway and Changcheng highway).

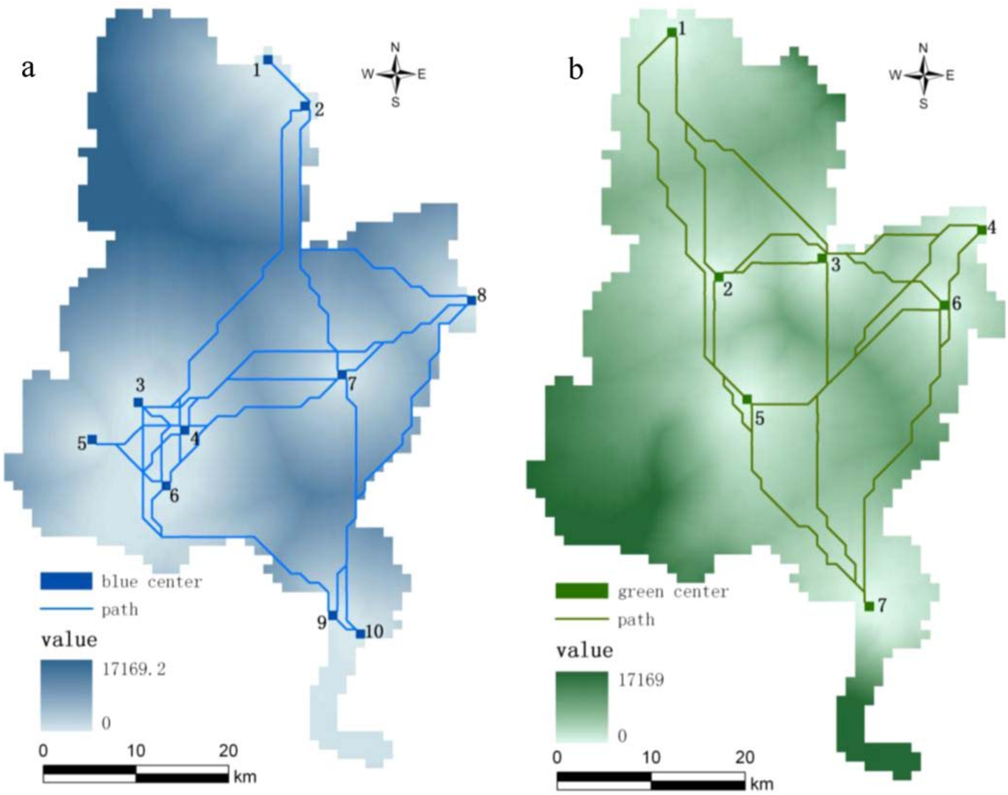

Fig. 5. Nodes and paths of ecological landscape networks. (a) Blue landscape network. (1, Desheng estuary; 2, Zaojiang estuary; 3, Gangkou; 4, Xihe; 5, Dashenjia; 6, Fangqian; 7, Songjianhu; 8, Xiliutang; 9, Baidu; 10, Taige). (b) Green landscape network (1, Huang mountain; 2, Qingfeng park; 3, Dinosaur park; 4, Shunguo mountain; 5, Yancheng; 6, Jilong mountain; 7, Longquan mountain).

landscape type, key functional nodes were natural conservation areas, mountains, forest, and urban parks. The average value of the Normalized Difference Vegetation Index (NDVI) in each grid represented the degree of vegetation coverage and could be used as a cost surface for the green landscape type.

Fig. 5 presents the overall spatial structure of the ecological landscape network. Overall structural connectivity or functional linkage in the blue landscape type is better than that of any other landscape because of the well-developed water system. For all nodes, the Songjian marsh in the middle was important for linking to other nodes. Through analyzing the spatial configuration of the green landscape network, it could be seen that the key green landscape nodes in Changzhou were far away from the urban core area, and the most densely linked nodes were urban parks.

4.3. Determining ecologically fragile areas in the ULP

Based on inspection of the landscape networks in Changzhou city, some functional conflicts could be observed between urbanization and ecological conservation. Before spatial reconfiguration and functional optimization are attempted, it is necessary to determine the position and spatial extent of some key landscape units. Using the difference-of-occurrence mechanism, the ecologically fragile areas could be classified into two categories (Fig. 6). The first consists of areas needing conservation, such as typical or unique ecosystems with high ecological value or fragmented landscapes with a sensitive or fragile geological environment (Fig. 6a). The second consists of functional conflict areas, for example ecological landscapes which are impacted by traffic paths (Fig. 6b and c). Through analysis of relationships among the main landscape types, it is possible to generate a simple qualitative assessment of the potential intensity of interaction and its effect on strengthening or weakening functional linkages and structural connectivity (Table 4). The ecologically fragile areas (Fig. 6d) are the key units that should be considered when designing the ULP. To improve structural connectivity and functional linkages in an ecological landscape network, expansion of green landscape along main traffic paths such as urban streets, highways, and railways could be achieved by planting trees, shrubs, or vines on walls or housetops. Because they are important attractions for urban tourism, the basic elements of the blue landscapes such as lakes, marshes, and waterways should be integrated into any future planning.

5. Discussions

By characterizing the landscape networks that exist in Changzhou city, this study has represented the linkage of function

Table 4
Qualitative description of interaction intensity among main landscape types.

	Red landscape	Gray landscape	Green landscape	Blue landscape
Red landscape	+	++	–	– –
Gray landscape	++	+	–	– –
Green landscape	–	–	+	+
Blue landscape	– –	– –	+	++

++: strong positive effect; +: moderate positive effect; – –: strong negative effect; –: moderate negative effect.

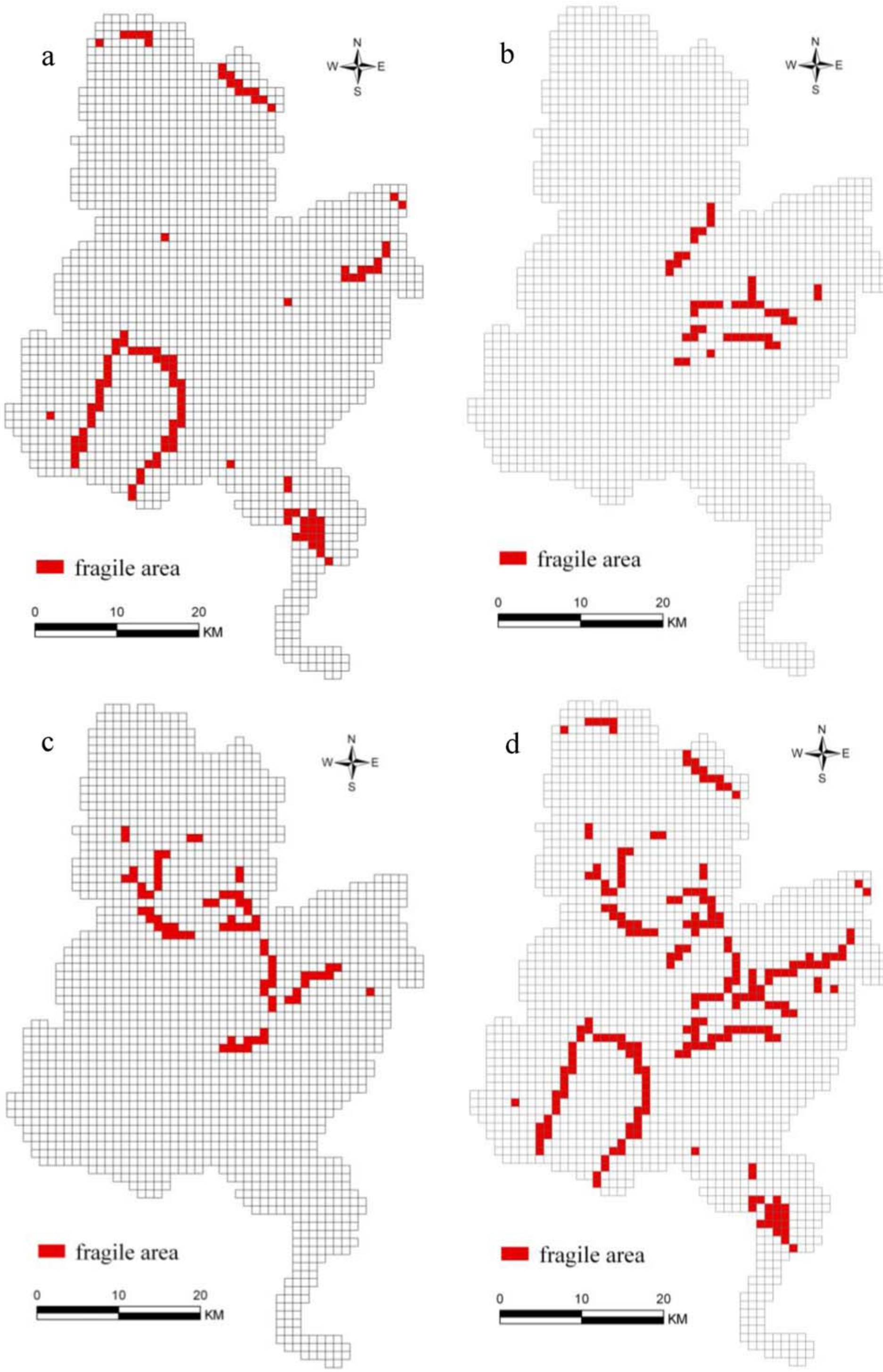

Fig. 6. Spatial distribution of ecological fragile area in grids. (a) Areas needing for conservation; (b) areas with functional conflict in blue landscapes; (c) areas with functional conflict in green landscapes; (d) overall spatial pattern of ecological fragile areas.

and configuration among the different landscape elements; further interpretation of the least-cost model would be of great benefit to discover potential conflict areas among landscape functions in Changzhou.

As described in Sections 2.1 and 2.2, landscape networks serve a number of important functions, and though potentially valued at different scales by different individuals, they are integrally related to the sustainability issues of urban development, freshwater resources, and assimilative capacity. They also support and augment the scientific, environmental, and recreational values of urban landscapes.

To ensure that the existing ecological resources are preserved and maintained, it is necessary to develop overall spatial strategies for future urban development. Based on the results of landscape network analysis and ecologically fragile area determination, spatial strategies for ULP design should specify prohibited areas, restricted areas, regulated areas, optimized areas, and potential development areas (Fig. 7).

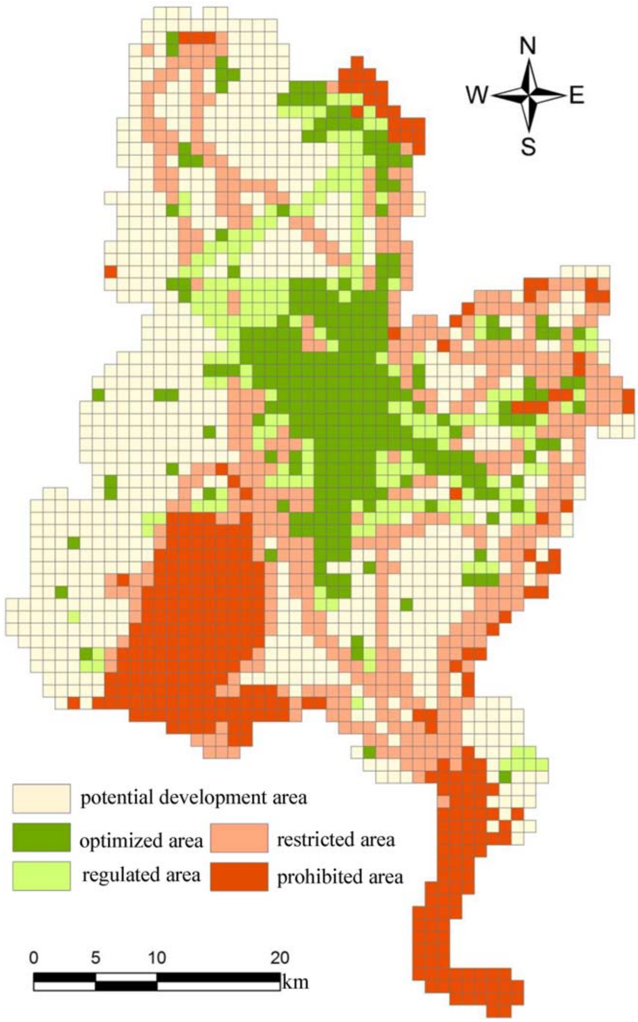

Fig. 7. Spatial design for ULP in Changzhou.

Prohibited areas should be composed of grid squares with more than 75% ecological landscape with high ecological value, such as natural conservation areas and important water sources along the Yangtze River, Tai Lake, and Ge Lake. Any form of land development should be prevented in prohibited areas. Restricted areas consist of buffer areas around the prohibited areas and ecological landscape corridors to maintain connections between ecological landscapes. These areas are undoubtedly useful in protecting large areas of natural land and important habitats in Changzhou, and they often encompass land which is largely undevelopable anyway. In regulated areas, land-use types should be adjusted to resolve functional conflicts and protect ecologically fragile areas. To these ends, industrial areas or traffic infrastructure which may cause air and water pollution should be modified in regulated areas. Optimized areas are characterized by intense socioeconomic activity and are composed of the urban core area and the major industrial area. Already-developed land and limited space should be used to greater advantage by rebuilding and efficient use. The potential development area, which does not now have a definite function or land-use type, will provide land for urban development in the future.

6. Conclusions

The importance of ecological landscapes to urban ecological security can hardly be overemphasized in our world where economic progress, indeed sustainable development in any form and every aspect of socioeconomic endeavors, continues to depend on a secure ecological foundation. Unless the components of urban ecological security are protected and maintained in a productive state to provide genetic diversity and hydrological and nutrient recycling functions, the future of the urban landscape itself will be at risk.

As a widely used concept in ecology and urban planning, the network proved to be a helpful concept for analyzing and explaining spatial correlations and the interaction of landscape functions. Through the analysis of interactions among landscape types, the construction and application of landscape networks can overcome to some extent the limitations of traditional pattern-based research methods and clarify the spatial characteristics of functional flows in landscapes. Landscape networks can also optimize the ULP through determination of ecologically fragile areas. In addition, defining different nodes and paths in landscape networks can integrate landscape elements with similar functions and alleviate or buffer the conflicts among incompatible functions. Moreover, networks also provide a research approach for optimizing landscape patterns.

Landscape functions are affected by spatial distance and the arrangement of landscape elements. Therefore, whether in its ecological protection or urban planning aspects, the linkage of landscape functions is closely related to landscape pattern connectivity. Using a least-cost distance model, landscape networks can shed light on the structural connectivity and spatial configuration of landscape elements and can also provide an analytical method to indicate functional linkages or conflicts. The identification of ecologically fragile areas is of great benefit in resolving landscape functional conflicts in the ULP.

The negative effects of human activities are causing a gradual shrinkage of ecological landscapes in urban areas. The greatest challenge here is to develop a common perspective on how to optimize urban ecological security patterns. From the viewpoint of the ULP design, it is necessary to strengthen the structural connectivity of ecological landscapes and to construct ecological networks to improve urban ecological functional linkages. In doing this, a spatial regime and strategy must be determined that takes into account, not only the fundamental principles of how nature functions, but also economic growth and social needs, and which does so in a way that is both equitable and enduring.

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